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ANNUAL REPORT
RANGE REVEGETATION INVESTIGATIONS

FORAGE & RANGE BRANCH
CROPS RESEARCH DIVISION
AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

INTERMOUNTAIN FOREST
AND RANGE EXPERIMENT STATION
and
UTAH AGRICULTURAL EXPERIMENT STATION

by

A. T. BLEAK, RANGE CONSERVATIONIST
EPHRAIM, UTAH

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Bureau of Land Management

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Utah State University

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Copies of this report were submitted to the following:

Two copies (1 and 2):
Forage & Range Branch
Crops Research Division
Plant Industry Station
Beltsville, Maryland

One copy (3):
Director
Intermountain Forest & Range Experiment Station
Forest Service, USDA
Ogden, Utah

One copy (4):
Director
Utah Agricultural Experiment Station
Utah State University
Logan, Utah

One copy (5):
Regional Coordinator
Forage & Range Section
Utah State University
Logan, Utah

One copy (6):
Project files
Ephraim, Utah

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I. INTRODUCTION -- CRc6: PASTURE AND RANGE INVESTIGATIONS UNDER ARID, SEMI-ARID, AND SUB-HUMID CONDITIONS INCLUDING SILAGE AND HAY PRODUCTION.

The following report covers the artificial revegetation investigations conducted in central Utah during the period April 1, 1958 to March 31, 1959. This is the third report that has been submitted since the work in central Utah was reactivated in the summer of 1956.

New work initiated included laboratory studies on seed germination; behavior of seeds and seedlings under a snow cover during the winter and spring months; damage to seeds or seedlings from fall plantings; and a study to determine if flooding occurred during rapid snowmelt in the spring. These studies were continued in 1957 and 1958 and similar studies based on this work have been initiated to further explore the factors influencing the success or failure on harsh sites, especially at high elevations.

A. Foreign Visitors and Technical Assistance

Approximately 5 hours were spent with Mr. Henery E. Connor from New Zealand and 8 hours were spent with Mr. Leonidas George Liacos from Greece. In addition 66 hours were spent giving technical assistance and reviewing research findings with extension workers, action agencies and private groups.

B. Vehicles at Ephraim, Utah

1. 1954 truck pickup, ½ Ton Ford V-2593-ARS, License A57211. Mileage on March 31, 1959 - 42,176.
2. 1955 truck pickup, ½ Ton Willys Jeep, V-2593-ARS, License A57211. Estimated mileage on March 31, 1959 - 30,000.

II. CRc6-2: EVALUATION OF GRASSES AND LEGUMES ALONE AND IN COMBINATION FOR ADAPTATION TO RANGE CONDITIONS

Suitable species are needed to increase forage production, to maintain soil stability and prevent destructive floods. Species should be used which are adapted to the environment. Species may be well adapted to a particular climate or soil but still fail because of some other environmental factors. This has led to an effort to distinguish between those inherent climatic and edaphic factors which must be met by species selection as opposed to factors such as grazing use, insects, rodents, and disease.

II-A. DESERT RANGE LANDS OF THE INTERMOUNTAIN REGION

Desert range lands of the Intermountain Region cannot be considered as a single homogenous type similar to the big sagebrush or pinyon-juniper types. These desert lands include two major types even when considered from a very broad point of view. The southern desert shrub type is characterized by high summer maximum temperatures, often above 100° F., for 5 or 6 months of the year, mild winters, and a drought period in both spring and fall. In the northern shrub type maximum temperatures above 100° F. are rare and there is usually a cold rest period during the winter and a drought rest period in midsummer. Only the northern desert shrub type will be discussed in this report.

The northern desert shrub type occurs mainly toward the southern and southwestern parts of the Intermountain Region. Big sagebrush is not considered to be a major species in the northern desert shrub type in this report. The largest continuous area extends from the Carson Desert of west central Nevada south and east to the dry mountain region of Death Valley and southern Nevada. This type forms a distinct zone between the sagebrush zone to the north and the southern desert zone to the south. A second large area lies in the arid portions of western Utah. A third area is located in the Green and Colorado River drainages of eastern Utah and western Colorado. Isolated islands of this type extend northward into eastern Oregon, southern Idaho, and southwestern Wyoming.

In general it can be said that the climate of this zone is distinctly drier than the sagebrush zone. The mean annual precipitation for six desert shrub stations in western Utah averaged 7.95 inches, while that for four sagebrush stations averaged 14.84 inches or again almost

twice as much as in the desert shrub type. Dr. D. W. Billings reported mean annual precipitation at 11 stations in western Nevada and eastern California in the northern desert shrub type ranged from 3.08 inches to 5.68 inches with an average of 4.51 inches for the zone. This is about one-half the average mean annual precipitation of 8.79 inches for 6 stations in the sagebrush zone in northern and western Nevada.

Mean January temperatures in the northern desert shrub appear to be higher than in the sagebrush zone. The summer temperatures of the northern desert shrub in western Nevada are distinctly higher, about 5° F., than those in the sagebrush zone. The higher summer temperatures in the desert shrub zone are undoubtedly reflected in higher evaporation, resulting when coupled with lower precipitation in greater aridity.

The northern desert shrub type can be conveniently broken down into several distinct communities or associations. These are permanent communities, to some extent determined by soil conditions within the limits set by climate. The most important or largest communities are listed below in the order in which they frequently occur in going from the big sagebrush type toward the heavier moister soils surrounding a lake or marsh on the valley floor.

1. Black sagebrush (Artemisia nova)
2. Galleta grass (Hilaria jamesi)
3. Little rabbitbrush (Chrysothamnus stenophyllus)
4. Winterfat (Eurotia lanata)
5. Shadscale (Atriplex confertifolia)
6. Greasewood (Sarcobatus vermiculatus)
7. Saltgrass (Distichlis stricta)
8. Pickleweed (Allenrolfea occidentalis)

Desert range lands of the Intermountain Region have been seriously depleted. At present there is urgent need to rehabilitate vast areas of these ranges to stop further deterioration by wind and water erosion, to stop deposition of sediment in lakes, reservoirs, and river basins like the Colorado and Virgin, to control noxious weeds, and to increase forage production especially on winter ranges for livestock and game.

Because of climatic conditions, returns from the land are low in the desert types as compared to other range types. From the evidence we have to date, vast areas can and should be rehabilitated through management. However, artificial revegetation is needed and justified on critical areas that need rapid rehabilitation and on better lands where the returns will offset the cost of operation.

In the pickleweed, saltgrass, and greasewood associations, physiological drought may be more of a problem than soil moisture. At this time, successful plantings can be made in the saltgrass and in some greasewood types. Experience has shown that these plants must be eradicated for successful artificial revegetation. Greasewood can be eliminated by wheatland plowing or similar methods. Saltgrass is more difficult to eradicate. The method which has given best results is to turn the sod completely under. This can best be done by moldboard plowing to a depth of 4 to 5 inches in the summer or fall when the soil surface is dry. Spring planting has been best on wet alkali lands and late fall or early spring planting is superior on dry alkali soils. Planting procedures which place the seed in a shallow furrow or depression have given better results than drilling directly into soil surface.

Species adapted to wet alkali areas with a high water table are tall wheatgrass, alta fescue, yellow sweetclover, fivehook bassia and Belvedere summercypress. Promising species on areas with a low water table which dries out in summer are tall wheatgrass, Russian wildrye and crested wheatgrass. On some of these areas, drought tolerance is more important than a tolerance to soil salts.

In the black sagebrush, galleta, winterfat, and shadscale associations, physical drought is the principal limiting factor. Plant growth is restricted by available moisture in the soil as a result of precipitation and soil characteristics. Drought tolerance is generally more important than tolerance to high concentrations of soil salts.

Most of the trial plantings on these desert range lands have resulted in failure. Good to excellent seedling stands of crested wheatgrass, desert wheatgrass, intermediate wheatgrass, pubescent wheatgrass, tall wheatgrass, bluebunch wheatgrass, Russian wildrye and many other grasses have been obtained in the spring at several locations in several years but most of the seedlings perished during the following summer. Desert wheatgrass and Russian wildrye appear to be the best adapted of the introduced grasses but even established stands of these grasses have usually perished during drought years.

Seed of grasses and shrubs collected from native stands have been planted at several locations in several years in both Utah and Nevada. Results have been erratic but where seedling plants were produced they usually perished during the first year. The few remaining plants have usually perished in subsequent drought years.

Average precipitation on the northern desert shrub type usually ranges from about 4 to 8 inches. Since most of the precipitation normally comes during the winter and early spring period available moisture is usually adequate for seed germination in the early spring period. Most of the introduced grasses will germinate at relatively low temperatures and seed germination from late fall plantings have been observed from early December through April depending on climatic conditions. If conditions are suitable for seed germination the seedlings usually perished unless subsequent storms provided additional moisture. During a severe drought in the fall of 1954 and spring of 1955 moisture was not adequate for seed germination on a planting near Yerington, Nevada. The seed laid over in the soil and many seeds of introduced grasses and some native grasses and shrubs germinated following rainstorms in September. A few seeds also germinated in the spring of 1956.

In general, little success has been reported from plantings of native grasses, herbs, or shrubs. However, native shrubs have withstood the frequent droughts much better than most introduced grasses. It would appear that future work with perennials on these desert lands should emphasize shrub species, both native and introduced.

II-B. LEGUME-GRASS MIXTURE

The advantages of grass-legume mixtures for conservation work and for pasture mixtures on farmland in sub-humid areas and under irrigation have long been recognized. However, little work has been done on grass-legume mixtures for western rangelands. Many of the legumes suited for irrigated land will not grow on the more arid rangelands. Many of these legumes have a single taproot which is easily destroyed by gophers or other digging animals, killing the plant.

This study is located on a small plot in the mountain brush type in Ephraim Canyon. Elevation is about 7,200 feet and annual precipitation is about 18 inches. The soil is a silt loam from limestone origin. The study site was cleared prior to planting. During the spring of 1950 the study area was burned. Stumps and remaining shrubs were cleared by disking and hand grubbing.

Prior to burning the vegetative cover was primarily big sagebrush interspersed with small patches of oak and snowberry. A few remnants of Agropyron spicatum, Sitanion hystrix, Oryzopsis hymenoides, and Lupinus could be found under the shrubby species. Bromus tectorum and other annuals were abundant in the openings.

This study was established to determine the best legumes for planting in grass-legume mixtures and determining the effects of the grass-legume mixture on yield of the grasses and legumes in range planting on mountain brush ranges.

Nine legumes including three separate strains of alfalfa were planted in mixture with each of four promising grass species in the fall of 1950. Species and strains used are listed below.

GRASSES

Agropyron desertorum - Lot Agcr 78, Commercial. Grown in Sanpete Valley, Utah in 1950.
Agropyron intermedium - Lot 42, Pullman, Washington SCS No. P-2327. Grown in 1945.
Bromus carinatus - Lot 32, progeny of native seed from near Enterprise, Utah. Grown in 1949.
Bromus inermis - Lot 47, Lincoln, progeny of certified seed. Grown in 1950.

LEGUMES

Astragalus cicer - Lot 9, Pullman, Washington SCS No. P-498. Grown in 1946.
Astragalus falcatus - Lot 11. Grown at SCS Nurseries in Bellingham Nursery. Received in 1948.
Lathyrus sylvestris - Lot 5, Pullman, Washington SCS No. P-27. Received in 1949.
Lotus corniculatus - Lot 5, Pullman, Washington SCS No. P-735. Received in 1949.
Medicago falcata - Lot 1A. Grown in 1947. Progeny of seed obtained from University of Alaska.
Medicago sativa - Lot Megl B. Progeny of A169, grown in 1950.
Medicago sativa - Lot 7, Ladak, Kelley Western Seed Company, certified. Grown in Idaho in 1945.
Medicago sativa - Lot 14, Rhizome, Northrup, King and Company, Lot N431. Grown in New Mexico in 1949.
Vicia tenufolia - Lot 6, Pullman, Washington SCS No. P-692. Grown in 1948.

An area 80 x 90 feet was divided into 4 equal blocks and each block was divided into 4 sub-blocks. Each sub-block contains 9 plots which are 5 feet wide and 10 feet long. Three furrows 20 inches apart were made the length of the plots. Seed of 1 grass species was placed in all furrows at a rate of 8 to 10 pounds per acre. Seed of each of the 9 legume species was planted at a rate of 8 to 10 pounds per acre. Assignment of grass species to sub-blocks was at random and placement of legume species within a sub-block is at random. Seed was then covered with soil to a depth of 3/4-inch and the soil was firmed.

During the period 1950 to 1953 the area was poisoned and trapped to keep pocket gophers and digging animals out of the study area. Plant numbers and yield were taken in 1951, 1952 and 1953. During the next 3 years this area was poisoned at intervals but in general natural condition in respect to grazing use by animal life prevailed. In the early spring of 1957 all old herbage from previous years was removed from the area, pocket gophers were poisoned and trapped, and a rabbit and deer exclosure was constructed around the study. In 1957 and 1958 the number of legume plants in each plot was counted. The legume plants were hand clipped on each plot and the grass was then mowed with a scythette. The legume and grass herbage was individually sacked and green weights were taken. Air dry weights were taken on all samples. Oven dry weights were taken on selected samples.

Analysis of data has not been completed at this time but the following conclusions can be made. Of the four grass species used, mountain brome was most compatable with the legume species used. However, this short-lived grass had largely died out by 1957. Herbage production of legumes was smallest when grown with intermediate wheatgrass. Legumes growing with crested wheatgrass and smooth brome produced similar yield. The strains of alfalfa were superior in both number and herbage production to other species, but Astragalus cicer also made a good showing. Astragalus falcatus and Medicago produced fair stands. Lathyrus sylvestris, Lotus corniculatus and Vicia tenufolia failed to produce fair stands in mixtures with these grasses on the mountain brush site.

Field work was terminated in the fall of 1958. This study should provide material for a paper in the Journal of Range Management.

III. CRc6-3: ESTABLISHMENT PRACTICES FOR REVEGETATION OF RANGE AREAS IN THE WEST

Suitable establishment practices are necessary for consistently successful and effective revegetation of depleted ranges on which the present plant cover is not adequate for soil protection or is of low forage values. The upper Colorado River Basin development provides for rehabilitation of this rangeland. This expanding reseeding program is moving work into the extremes of climate and soils on which little is known about reseeding. This magnifies the importance of "know-how" in restoring the vegetation cover. Low precipitation, dry summers, sandy soil, acid soil, steep slopes and rough terrain are some of the factors which require special consideration.

III-A-1. Observations on seed germination and behavior of seven species under natural conditions at three field locations fall and winter of 1957 and spring of 1958

The purpose of this study was to determine the relative behavior of seeds of seven grass species in relation to existing natural environmental condition at three locations during the fall, winter, and spring. Information on when seeds germinate, rate of growth in roots and shoots, damage to seeds and seedlings by frost, damage to seeds by pathogens, and other factors, is needed to better understand why fall plantings fail or succeed.

Sites used for this study are located in Sanpete County in central Utah. One area is approximately 1 mile southeast of Ephraim, Utah and the other two areas are in the mountain brush type and aspen-fir type respectively in Ephraim Canyon. (1) The area near Ephraim, Utah is in the sagebrush type. It is located at an elevation of 5,500 feet on an alluvial fan formed by Ephraim Creek. Average annual precipitation is slightly less than 11 inches per year. Average frost free period for this site is approximately 120 days. Native vegetation on natural areas in this type is predominantly big sagebrush. Such species as Indian ricegrass, bluebunch wheatgrass, and western wheatgrass were reported to be abundant prior to heavy grazing use by livestock but now occur only in limited amounts. Cheatgrass and squirreltail are now the most abundant grass species. Soils are a shallow loam of limestone origin. (2) The mountain brush site is located on a silt loam of limestone origin at an elevation of 7,200 feet. Average annual precipitation is about 15 to 18 inches and the frost free period is approximately 90 days. Native vegetation consists primarily of patches of gambel oak, inter-

spersed with other shrubs such as big sagebrush, serviceberry, and mountainmahogany. A moderate number of grasses and weeds occur as an understory. (3) The aspen-fir site is located at an elevation of 8,850 feet on a clay-loam of limestone origin. The climate is characterized by a short favorable growing season with frequent frost occurring during the early and late snow free periods. The dominant vegetation is scattered patches of aspen and fir. The understory is made up of snowberry and a mixture of mountain brome, slender wheatgrass, and broad leaved herbs.

Species used in this study and pertinent information on these seven species follow: Nordan crested wheatgrass, F.C. 33091, grown at Mandan, North Dakota in 1955. Intermediate wheatgrass - Northrup-King Company, #D6-1, grown in Washington. Native slender wheatgrass - harvested at an elevation of 9,400 feet in Ephraim Canyon in September 1957. Tall oatgrass - grown in Virginia in 1955, Snelson Seed Company, (No. 633) Atlanta, Georgia. Native mountain brome - harvested at an elevation of 9,000 feet in Ephraim Canyon in September 1957. Manchar smooth brome - grown in Oregon in 1952, certified, No. 103019. Red fescue - grown in Oregon, certified, Northrup-King, #6178.

This study was based on information obtained from field germination studies conducted at Philadelphia Flat and Headquarters Station in the fall of 1956 and winter and spring of 1957 as well as laboratory studies made in the summer and fall of 1957.

Sacks containing 100 seeds of a single species were planted at a depth of 2 centimeters (3/4-inch) at each location. Sacks were placed in groups with seven sacks containing the seven species in each sampling unit or replication. Due to the very rapid deterioration of these cotton

sacks all sacks were placed on fiberglass screen. Planting procedures were as follows: Two centimeters of soil was first removed from the planting area, a piece of fiberglass screen approximately 5 inches wide and 36 inches long was laid on the exposed soil. The seven sacks were placed at random along the fiberglass screen and the original soil cover was placed over the sacks and screen. Soil was then firmed over the sacks.

At the sagebrush and mountain brush sites the sampling groups were placed between two rows of marker stakes so that the seeds could be easily located. This arrangement was not suitable at the aspen-fir site since a heavy snow cover is normal during the winter months. To make location of seeds possible after deep snow was on the ground at the aspen-fir site, long stakes (8 feet) were placed in line at intervals of 10 feet. A 6 x 6 foot area was located with its center 10 feet north of each location stake. These 6 x 6 foot areas were then cleared of all vegetation. Two units or replications of 7 sacks on fiberglass screens were then planted together within each of the 6 x 6 cleared areas. A total of 26 sampling units or replications were planted at each site. This study was established to provide 13 separate sampling dates with 2 replications of 7 sacks to be removed from each site on each sampling date. All sampling was at random except that the two sampling units of 7 sacks placed together in the aspen-fir type were removed on the same sampling date.

Seed was placed in the ground at the aspen-fir site on October 31, 1957. Approximately 2 inches of snow was removed from each area prior to planting and returned after planting was completed and 4 inches of new snow fell during the night of October 31. Thus the aspen-fir site was under a continual snow cover from the planting date until spring snowmelt. Seed was placed under the soil at the sagebrush and mountain brush site on November 1, 1957. The mountain brush site was under snow cover most of the time but the snow was shallow. The sagebrush site was under shallow snow cover during most of January and February and occasionally during November and December.

Climatic stations were set up at each site prior to planting or plantings were made near established climatic stations operated by the Forest Service. At each site equipment was present to measure continuous air temperature at 4 feet above the soil, separate maximum and minimum temperatures on a weekly basis, continuous soil temperature at 3/4 of an inch below the soil surface, intermittent electrical measure of soil temperature and soil moisture at the soil surface, and at depths of 3/4, 6, 12, 24, and 48 inches. In addition, temperature and moisture units were placed in the snow at 3/4-inch and 6 inches above the soil surface at the aspen-fir site. Continuous air and soil temperatures were usually taken with 2-pen thermographs. Soil moisture and soil temperature readings were taken on Monday of each week with Coleman blocks and a Coleman meter. Additional soil moisture determinations were taken by the gravimetric system. All climatic stations were visited on Monday of each week and supplemental information such as the depth of snow, presence of ice and similar information was recorded.

Soil temperatures at a depth of 3/4 inch were above freezing when the permanent winter snow fell in October 1957. This snow protected the soil from freezing and it came at a time when soil temperatures to a depth of at least 4 feet were relatively high. Snow depth during the winter of 1957-1958 varied from 12 inches on November 1 to 74 inches on April 14 and was still 26 inches deep on May 12, 1958.

On the first 10 sampling dates sacks were removed from all areas on the same day so that seed behavior on the different sites could be compared by dates. In general the sagebrush site was relatively free of snow and the top 1 to 3 inches of soil was frozen and thawed intermittently. At the mountain brush site the soil was frozen from a depth of 1 to 6 inches for a large portion of the winter, although a shallow snow cover had been on the ground most of the time. A continual snow cover was on the aspen-fir site since the day the seeds were placed under the soil. A thin ice crust 1/8 to 1/4 inch thick was observed just above the soil on several sampling dates, but the soil at a depth of 3/4 inch remained near 32° F and was thawed and moist when all weekly readings were made.

Sacks containing seed were removed every 2 or 3 weeks throughout the winter. At the aspen-fir site it was necessary to dig through a relatively deep snow cover to reach the seed. When the soil was frozen, as occurred several times at the mountain brush site, and twice at the sagebrush site, it was necessary to chop through the ice and frozen soil around the fiberglass screens. The fiberglass screens were then easily separated from the frozen soil below without damage to the sacks and the remaining soil was carefully removed. Some damage occurred to roots

and shoots protruding through the sacks but this could not be avoided. The fiberglass screens placed below the sacks greatly facilitated the removal of the samples since all sacks were easily located. At the aspen-fir site the screens were especially valuable since the cotton sacks were attacked by fungi, bacteria, or other organisms and literally fell to pieces.

Care was taken in removing all sacks. The sacks were carefully examined for protrusion of roots and shoots. All samples were labeled and placed in small plastic bags where they were held at near freezing temperatures until they could be examined in the laboratory. The bags were opened in the laboratory and observations made on total number of seeds that had started to germinate. Maximum and average length of shoots and roots were measured and observations on appearance and condition of seeds were made. All seeds or seedlings were then placed on moist silica sand in small plastic boxes with self-sealing lids and placed in a germinator at alternative temperatures of 28° C for the first 8 hours in each day and at 20° C for the remaining 16 hours in each day. Daily observations were made for the first 2 days and periodic counts were made on all additional germination. After the second day and on subsequent observations, all seeds that developed normal roots and shoots were removed and discarded. All samples were held at favorable germinating temperatures for 6 weeks or more when final counts were made and the samples were discarded.

All areas were first sampled on November 17, 16, or 17 days after planting, and at intervals of 2 or 3 weeks during the winter and spring of 1958. The last uniform sampling date at all three sites was on April 7, 1958. On this date the snow pack at the aspen-fir was 74 inches deep. The mountain brush site had a snow cover of 2 inches and the soil was frozen to a depth of 1/2-inch. The sagebrush site was free of snow, green growth on established crested wheatgrass plants was about 3 inches high, winter moisture had penetrated to a depth of 4 feet or more and the soil below 6 inches had started to warm.

Subsequent samples were taken at the sagebrush and mountain brush sites on 4/21 and 5/5. The soil was drying at both locations on 4/21 and by 5/5 the soil below the seed was very dry. Drying of the soil at these sites would normally have occurred prior to April 7 but frequent spring storms kept the soil moist.

Subsequent samples were taken at the aspen-fir site on April 29, May 22 and July 15. Snow depth was 55 inches deep on April 29 and about 13 inches deep on May 22 and snow was completely gone from the area on May 24. The last sample was removed on July 15 after all surviving plants were established.

Seed germination and behavior during the winter and spring varied considerably between species at a given site and between the three different sites. On November 17 only crested wheatgrass had started to germinate on all three sites but intermediate wheatgrass had also started to germinate at the sagebrush site. Germination on December 2 and all subsequent samples at the time they were removed from the soil, except for the July 25 sample from the aspen-fir site are shown in table 1.

Table 1 .--Average germination in percent for seed of 7 species planted in aspen-fir, mountain brush and sagebrush types in the fall of 1957 and removed at intervals during the winter and spring of 1958.

	Date samples were removed										
Species	12/2	12/16	12/30	1/13	2/3	2/24	3/10	3/24	4/7	4/21 1/ & 4/29	5/5 2/ & 5/22 3/
Crested wheatgrass											
Aspen-fir	10.0	62.0	63.5	74.5	75.0	83.5	87.0	87.0	82.0	81.5	90.0
Mtn. brush	16.0	36.5	70.5	57.5	65.5	64.5	82.0	82.5	69.5	84.5	86.5
Sagebrush	30.5	66.0	88.5	74.5	87.0	81.5	90.0	80.0	91.5	94.5	90.5
Intermediate wheatgrass											
Aspen-fir	2.5	5.5	9.5	23.0	28.5	60.5	66.0	66.0	65.0	77.0	77.5
Mtn. brush	2.0	7.5	7.0	2.5	3.5	14.5	23.5	34.0	43.0	53.0	76.5
Sagebrush	12.0	42.0	43.5	29.5	39.5	76.5	87.5	76.5	75.0	81.5	82.5
Slender wheatgrass											
Aspen-fir	0.0	0.0	0.0	0.0	1.0	15.5	61.0	78.5	92.0	93.5	94.5
Mtn. brush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.0	74.5	83.5
Sagebrush	0.0	0.0	0.0	0.0	0.0	6.0	57.0	77.0	65.5	86.5	75.0
Tall oatgrass											
Aspen-fir	0.0	9.5	25.0	37.0	54.5	79.5	83.0	84.0	83.0	82.0	80.0
Mtn. brush	0.0	0.0	0.0	0.0	0.0	7.0	12.0	9.5	10.5	37.5	73.5
Sagebrush	0.0	13.0	16.5	10.0	6.5	20.5	73.5	59.0	69.5	75.5	67.0
Mountain brome											
Aspen-fir	0.0	0.0	14.0	49.0	60.5	80.0	79.0	65.5	86.5	86.0	84.0
Mtn. brush	0.0	0.0	0.0	0.0	0.0	3.5	5.5	15.5	18.5	39.0	68.0
Sagebrush	0.0	0.5	0.0	0.0	0.0	16.5	50.5	62.5	37.0	79.0	65.0
Smooth brome											
Aspen-fir	3.5	3.5	9.5	15.0	14.5	19.5	32.5	41.5	36.5	32.5	41.5
Mtn. brush	4.5	2.0	4.0	2.5	2.0	4.5	4.0	4.5	5.0	45.0	56.0
Sagebrush	3.5	5.0	6.0	10.0	15.5	28.0	51.5	65.0	60.5	63.0	73.5
Red fescue											
Aspen-fir	0.0	0.0	1.5	1.5	6.0	10.0	19.0	24.5	36.0	40.5	44.5
Mtn. brush	0.0	0.5	0.0	0.0	0.0	3.0	2.0	2.5	3.0	24.0	92.5
Sagebrush	0.0	0.0	0.0	0.0	5.0	12.5	49.0	61.0	82.0	78.0	82.5

1/ Sample removed from the aspen-fir site on 4/29/58
2/ Sample removed from the aspen-fir site on 5/22/58
3/ Seed and soil drying at sagebrush site

By February 24, 1958 some seed of all seven grasses had started to germinate, roots of some seedlings were over 1 inch long and some shoots of crested wheatgrass were above the soil surface at the aspen-fir site. Seed germination at the sagebrush site with intermittent snow cover was similar to the aspen-fir site but seed germination of all species at the intermediate, mountain brush site was slower than at either the aspen-fir or sagebrush sites. A difference in growth was still apparent on March 24 as shown in figure 1 . Seedlings at the sagebrush site were often above the soil surface growing rapidly in the warm moist soil.

The twelfth and last seed samples were removed from the mountain brush and sagebrush sites on May 5, 1958. The upper inch of soil was dry and seeds were drying but some shoots of all species were from 1 to 3 inches above the soil surface and growing vigorously. The twelfth seed sample was removed from the aspen-fir site on May 22, 1958 just two days before the snow melted. Some shoots of all species were protruding into the snow above the soil surface (figs. 2 and 3).

Decomposition of the cotton material by fungi and bacteria was quite marked at the aspen-fir site but at the sagebrush and mountain brush sites little decomposition occurred. Most of the roots and shoots penetrated the cotton material at the aspen-fir site. At the mountain brush and sagebrush sites most of the roots penetrated the cotton material but between 4 and 42% of the shoots remained within the bag. Nearly all of the shoots of mountain brome, intermediate wheatgrass, and slender wheatgrass penetrated the cotton material but shoot penetration of other species was retarded especially after the soil began to dry.

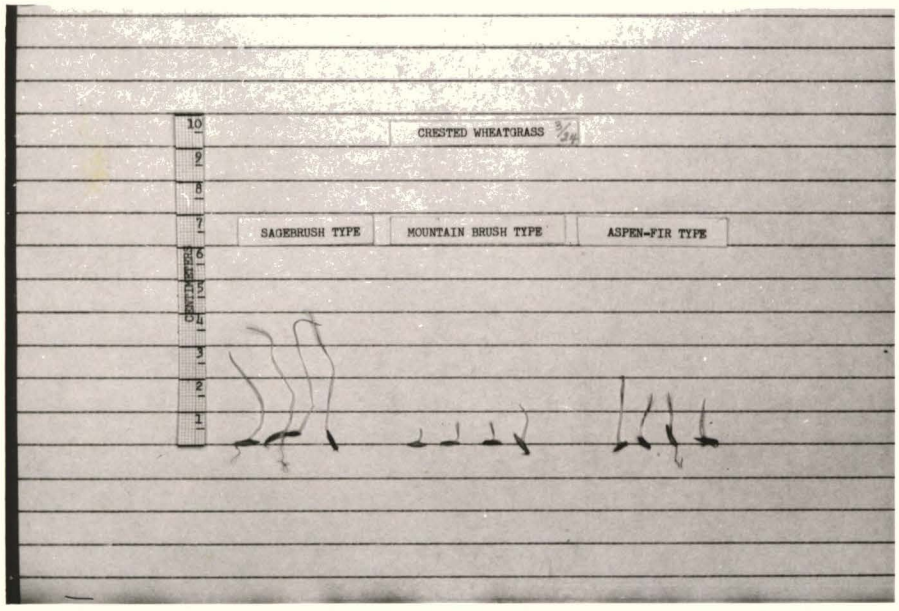
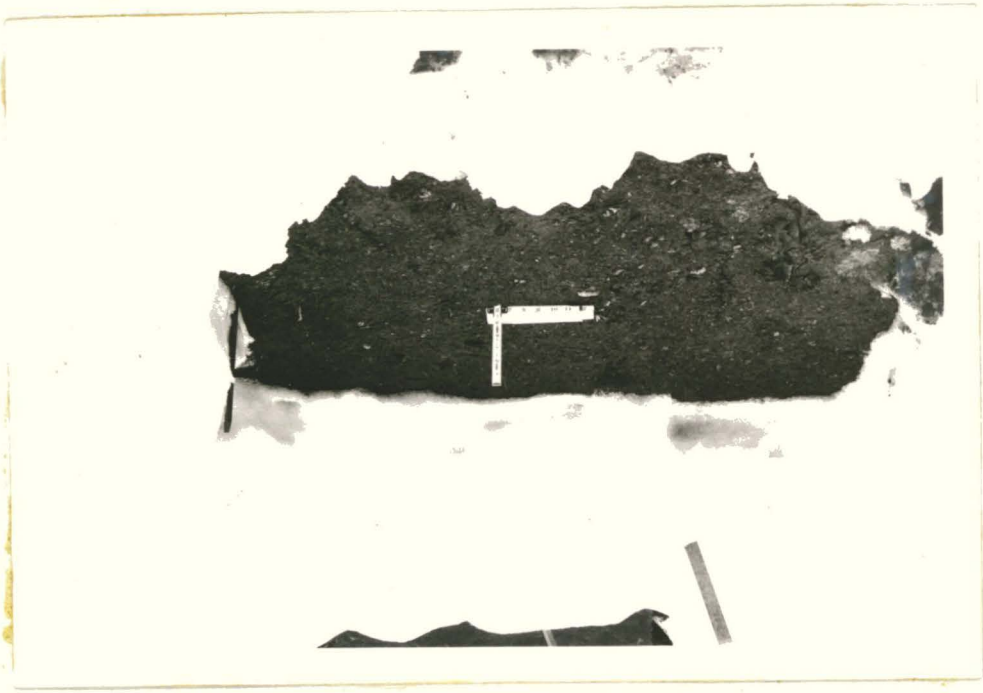


Figure 1 .--Growth of crested wheatgrass seedlings at the intermediate mountain brush site was much slower than at either the aspen-fir or sagebrush sites.



Figures [2] and 3.--The twelfth seed sample was removed from the aspen-fir site on May 22, 1958. Some shoots of all seven species were above the soil surface and protruding into the snow prior to removal of the snow.

Seeds or seedlings removed from the cotton bags were placed on moist sand in small plastic boxes. The percent of seeds that had produced seedlings with roots and shoots prior to removal from the soil or within 35 days after they were placed in the germinator are shown in table 2 . Some of the seeds removed from the mountain brush and sagebrush sites on May 22 had produced roots and shoots but had dried and did not make any additional growth in the germinator. Low germination in the native mountain brome and slender wheatgrass during the early sampling dates indicates that seed dormancy was not fully broken on these dates.

Table 2 .--Average percent of seeds of 7 species planted in aspen-fir, mountain brush and sagebrush types in the fall of 1957 and removed at intervals in the following winter and spring producing vigorous seedlings with both roots and shoots during a 35 day germination period.

	Date samples were removed										
Species	12/2	12/16	12/30	1/13	2/3	2/24	3/10	3/24	4/7	4/21 1/ & 4/29	5/5 2/ & 5/22 3/
Crested wheatgrass											
Aspen-fir	80.5	87.5	68.0	80.0	77.5	75.0	82.0	78.0	57.5	36.0	89.5
Mtn. brush	71.5	78.0	85.0	46.5	52.0	58.0	72.0	68.0	58.5	81.5	85.0
Sagebrush	80.0	83.0	96.0	79.0	74.0	86.5	85.5	61.5	77.5	91.5	90.5
Intermediate wheatgrass											
Aspen-fir	88.0	85.5	88.5	86.5	87.5	83.0	84.5	75.5	80.5	81.0	84.5
Mtn. brush	87.5	87.0	86.5	78.0	69.5	80.0	67.5	73.5	67.5	79.0	79.0
Sagebrush	83.0	89.5	82.0	74.5	70.5	87.0	79.0	64.0	57.0	78.5	82.0
Slender wheatgrass											
Aspen-fir	2.0	3.5	5.5	13.5	37.5	67.5	77.5	91.0	93.0	92.5	96.5
Mtn. brush	4.5	3.5	3.0	2.0	11.5	26.0	19.5	37.5	52.5	91.5	90.0
Sagebrush	7.0	7.5	3.5	2.0	4.0	46.0	68.0	85.0	65.0	86.5	74.5
Tall oatgrass											
Aspen-fir	58.5	60.0	55.0	37.5	65.0	78.0	74.5	79.5	75.0	77.0	86.5
Mtn. brush	52.0	36.5	33.0	43.5	43.0	41.5	24.0	31.0	40.5	44.5	76.0
Sagebrush	39.5	51.0	49.5	52.0	35.5	43.5	67.0	28.5	33.0	57.5	70.0
Mountain brome											
Aspen-fir	2.0	17.0	51.0	65.5	68.0	80.5	77.0	67.5	84.5	83.5	83.5
Mtn. brush	0.5	0.0	0.0	0.0	1.0	11.5	10.5	17.5	24.5	45.0	67.5
Sagebrush	1.5	3.0	3.5	0.0	5.0	28.0	38.5	45.5	32.5	75.5	60.0
Smooth brome											
Aspen-fir	83.0	84.0	69.5	78.5	71.5	66.5	77.0	51.0	39.0	76.0	67.0
Mtn. brush	75.5	87.5	74.5	75.5	60.5	64.0	60.0	63.0	53.0	51.0	57.5
Sagebrush	63.0	75.0	51.0	52.0	44.5	46.0	37.5	41.0	34.5	52.0	71.0
Red fescue											
Aspen-fir	93.0	95.0	88.0	90.0	90.5	74.5	98.0	88.5	82.5	76.0	70.0
Mtn. brush	91.5	97.0	91.5	86.0	90.0	93.0	85.0	91.0	91.5	79.0	89.0
Sagebrush	81.0	90.5	76.5	82.0	76.0	81.5	71.0	61.5	60.0	65.5	84.5

1/ Aspen-fir sample taken on 4/29
2/ Aspen-fir sample taken on 5/22
3/ Seeds in sagebrush drying and seeds in mountain brush drying when removed

III-A-2. A study of seed germination and behavior under winter snow and during rapid spring snowmelt during the spring of 1958 on Philadelphia Flat

This study was established to provide additional information on the factors which may limit or curtail germination, emergence and establishment of common grasses from fall plantings at high elevations. The treatments, procedures, and methods used were largely based on the studies conducted in the winter of 1956-1957 and spring of 1957 on this area and at the Headquarters Station.

The 1957 studies demonstrated that some seeds of smooth brome germinated and were growing under a snow cover of 74 inches at Headquarters Station prior to March 5, 1957. The date of seed germination on Philadelphia Flat in the spring of 1957 could not be determined because the area was not visited until May 15 and seed samples could not be located until June 7, when snow depth had decreased to about 5 feet and plot markers were located. These studies also demonstrated that viability of some of the remaining seeds had been reduced. This was especially noticeable on this area where many of the remaining seeds were black and appeared to be dead.

Seeds of native mountain brome, collected at 9,000 feet in the fall of 1957 in Ephraim Canyon; native slender wheatgrass, collected at 9,400 feet in the fall of 1957 in Ephraim Canyon; Manchar smooth brome, certified, No. 103019, grown in Oregon in 1952; and tall oatgrass, grown in Virginia in 1955 were used in this study. One hundred seeds of a single species were placed in small cloth bags and the openings were closed and stitched. Bags were color coded with ink to insure species identification in the field.

The study area used was prepared during the late summer and fall of 1957. Since gophers had been a problem in the 1957 study on this area they were trapped on the surrounding area during September and October. Three areas approximately 100 feet apart were staked so that sacks could be located after deep snow covered the site. Center stakes with the tip 8 feet above the soil were placed in the middle of each area. These stakes were in line and formed a base line. Four radius stakes, 7 feet long, were placed 20 feet from each center stake on both sides of the base line and at an angle of 30 degrees from the base line. Thus two radius stakes and the center stake were in line.

Four "planting" treatments were used in this study. These included planting in native soil, planting in sand pits placed in the soil, planting on sand mounds and suspended in the snow, approximately 4 inches above the soil surface (figs. 4 and 5). Sand pits were made by removing native soil from an area 3 feet square and 5 inches deep and replacing it with builder's sand. Sand mounds were made by building a frame 3 feet square and 5 inches high out of galvanized wire screen supported by lath stakes at all corners and at intervals along the sides. This frame was filled with builder's sand. Wooden frames 2 feet square and 6 inches high were made without tops or bottoms to hold the sack of seed up in the snow. Ends of the frames were solid but the sides were partly open to allow lateral movement of snow by wind, gravity, and etc. Four nylon chords were stretched across the top of the frames and sacks were stitched to the nylon chords.

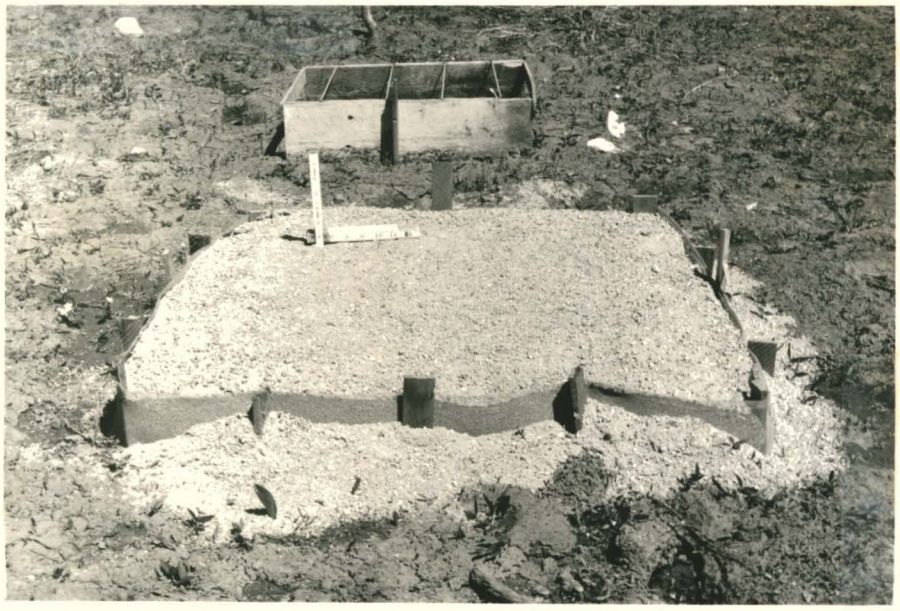


Figure 4 .--Seeds in bags planted in sand at a height of 4 inches above the native soil surface and suspended in the snow in the fall of 1957 were removed at intervals during the spring of 1958 (ATB-58-137).

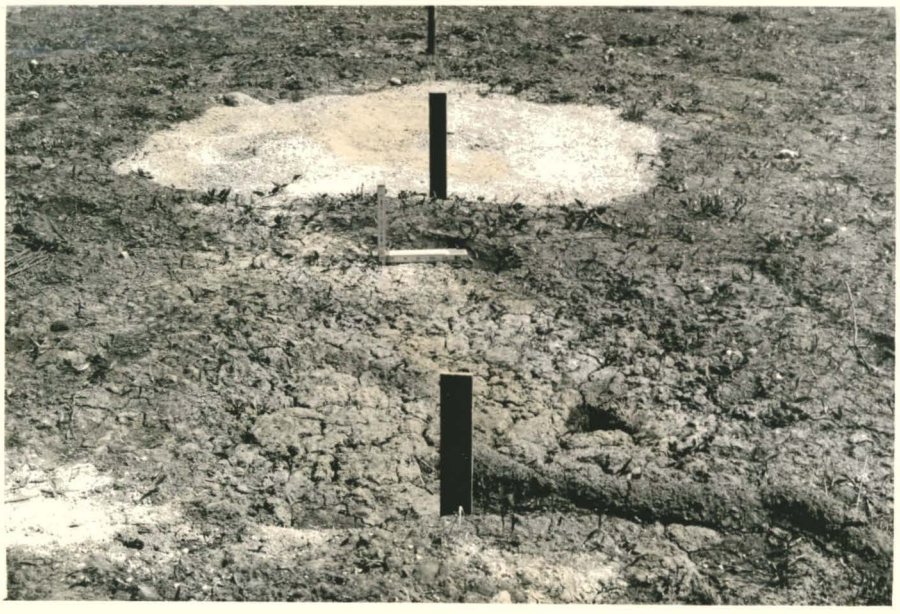


Figure 5 .--Seeds planted under 2 cm. of native soil and under 2 cm. of builder's sand in the fall of 1958 were removed at intervals during the spring of 1958 (ATB-58-138).

Since the cotton sacks rotted away in the 1956 planting, making seed removal very difficult, plastic screens were placed below all cloth sacks at the time of planting in the fall of 1957. Sand and soil was scraped from the planting area to a depth of 2 cm. Strips of plastic screen 5 inches wide and 2 feet long were placed flat on the sand or soil. Sacks were then placed on the screen and the sand or soil which had been removed was placed over the sacks, making a soil or sand covering 2 cm. thick. The four treatments within one sampling site were located between two adjoining radius posts and the center posts. Two of these treatments were between each radius post and the center post. One treatment in each pair was 7 feet from the center post and the other was 7 feet from the radius post. Location of the treatments at each sampling site was at random.

Plantings under the sand and soil were made on October 15 when the snow was 5 inches deep. Sacks were suspended in the snow on October 21 after the snow was 8 inches deep and by October 23 the snow depth had increased to 14 inches. In addition, a direct seeding of these species was made in furrows 40 feet long on October 10, 1957. Additional plantings were made in the spring of 1958 soon after the snow melted from the study area.

Heavy rain and snow storms during the period October 1 to October 23 resulted in puddling and soil saturation. Water up to 3 inches deep was observed in low areas and drainages but free water traps were not filled. Infiltration rate of the soil appeared to be very low. On October 29, the soil was very moist and free of frost. Additional

snow fell on October 31, 1957 increasing the snow pack to an average 27 inches. Snow depths in the winter of 1957-1958 are shown below.

Date	Snow depth Inches
October 15, 1957	5
October 23, 1957	14
October 31, 1957	27
January 1, 1958	42
February 1, 1958	59
February 28, 1958	78
March 28, 1958	88
April 7, 1958	108
April 21, 1958	80
April 30, 1958	82
May 5, 1958	66
May 12, 1958	63
May 19, 1958	55
May 29, 1958	34
June 2, 1958	26
June 4, 1958	19
June 6, 1958	8
June 7, 1958	0

The first seed samples were removed on February 28, 1958. Depth of snow averaged 78 inches. Many crusts were found in the snow and a thin ice crust was observed just above the soil surface but the soil surface was not frozen. The soil was wet and appeared to be near saturation. Sand was quite dry in comparison to the soil. Sand in the sand mound was frozen at the surface but not at a depth of 3/4 inch. Sacks suspended in the snow had been pressed down but were still 2 inches above the soil surface.

Some seed germination had taken place on all four planting locations (table 3). Roots were protruding through the bags at all four sites and appeared to be longest in the sand. Sacks were very rotten in the soil but were still in fair condition in the sand and snow, however fungi were working on all sacks. Seed of lupine and other

Table 8 .—Average germination in percent for seed of 4 species placed in snow under 3/4 inch of sand in a sandhill 4 inches above soil surface, under 3/4 inch of sand in a pit filled with sand and under 3/4 inch of soil in the fall of 1957 and removed at intervals during the winter and spring of 1958

	Dates Samples Were Removed					
Species	2/28	4/21	5/12	5/29	6/6	6/12
Slender wheatgrass						
Snow	7.0	52.0	41.7	72.0	84.0	1/
Sandhill	15.7	79.0	85.3	88.3	91.7	92.0
Sand pit	41.3	86.3	94.3	90.0	95.3	90.7
Soil	69.7	95.3	95.0	95.7	96.0	98.0
Tall oatgrass						
Snow	35.3	41.3	73.0	62.7	84.0	1/
Sandhill	71.7	74.7	80.0	71.0	87.7	75.0
Sand pit	81.3	86.3	81.7	82.7	88.0	82.0
Soil	79.7	72.3	77.0	85.3	80.3	85.3
Mountain brome						
Snow	3.7	22.7	4.7	9.0	8.3	1/
Sandhill	75.7	81.0	80.7	66.0	81.0	85.3
Sand pit	68.3	67.3	76.7	66.0	66.7	69.3
Soil	57.3	53.0	72.7	66.3	68.7	55.7
Smooth brome						
Snow	10.3	.3	11.3	15.0	13.3	1/
Sandhill	27.7	12.0	18.0	24.3	18.7	27.3
Sand pit	45.3	48.0	58.0	40.7	34.7	51.0
Soil	47.7	37.3	26.3	32.0	14.0	38.3

1/ No sample taken - snow melted on 6/7/58.

native species had germinated and were growing on the soil surface. Mountain brome had started to grow and new shoots were 3/4-inch long. Other plants such as slender wheatgrass and dandelion were starting to grow. Leaves and flowers of claytonia were found just below the soil surface.

On ~~March~~ April 7 snow depth was 108 inches deep and plot markers could not be located. By ~~March~~ April 21 snow had dropped to 80 inches and stakes were visible and the second seed sample was removed. Sacks in the soil were very rotten and difficult to handle. Sacks in the snow were covered with considerable fungi and some disintegration was observed but sacks in the sand were still in fair to good condition. A thin film of ice was observed over the soil but the soil was not frozen and appeared to be at or near saturation. The surface of the sand in the pit and mound was frozen to a depth of about 1/4 inch. The sacks in the snow were frozen stiff.

Additional seed samples were taken on May 12, May 29, June 6 and June 12. The June 6 sample was taken during very rapid spring snowmelt and when the snow depth averaged only 8 inches. Philadelphia Flat was flooding on this date and the plot area was covered with 1 to 2 inches of water. The sixth and last sample was taken on June 12 after snow disappeared from the flat area. Samples placed in the snow were not taken on this date. These sacks had dried out after the snow melted and many of the seeds were destroyed by a pocket gopher that ate most of the seed.

Seeds of all species had germinated under the snow on all locations. Seed germination in the snow was less than at the other three locations (sand mound, sand pit and soil) except for the sample of tall oatgrass removed on June 6. As shown in table 3 seed germination of slender wheatgrass, tall oatgrass and mountain brome in sand and soil under the winter snow cover exceeded 50% by April 21 when the second seed sample was removed.

Seeds removed from the sacks were placed in the germinator for a minimum of 35 days. Seeds that had developed healthy roots and shoots either under the snow or during the subsequent germination period in the laboratory are shown in table 4.

Table 4 .--Average percent of seeds of 4 species placed in snow, sandhill, sand pit, or under soil on Philadelphia Flat in the fall of 1957 and removed at intervals in the following winter and spring that produced vigorous seedlings during a 35 day germination period

	Dates Samples Were Removed					
Species	2/28	4/21	5/12	5/29	6/6	6/12
Slender wheatgrass						
Snow	23.7	64.3	58.3	77.7	84.0	1/
Sandhill	50.7	85.7	86.3	89.7	91.7	92.3
Sand pit	75.3	88.0	94.3	91.3	95.3	91.3
Soil	77.0	96.3	93.7	96.0	97.3	98.0
Tall oatgrass						
Snow	41.3	46.3	79.0	79.3	86.3	1/
Sandhill	69.0	71.0	84.3	84.7	90.0	89.0
Sand pit	84.3	74.0	88.0	86.7	91.0	91.7
Soil	75.3	58.3	77.7	83.7	83.7	90.7
Mountain brome						
Snow	8.3	23.3	8.0	9.0	8.0	1/
Sandhill	70.3	72.0	79.7	67.3	81.7	84.3
Sand pit	69.0	60.3	74.7	66.7	66.0	70.0
Soil	50.0	49.7	69.0	63.0	70.0	62.0
Smooth brome						
Snow	80.7	64.7	80.7	77.7	75.0	1/
Sandhill	80.3	57.7	80.7	76.0	77.0	75.0
Sand pit	81.7	57.7	88.7	81.3	83.3	84.7
Soil	59.0	29.7	38.0	61.0	29.3	52.7

1/ No sample taken - snow melted on 6/7/58.

III-A-3. Vegetative growth of some cool season plants in the Intermountain Region as affected by soil moisture and temperature

The annual growth of many perennial plants is cyclic in nature and largely determined by available moisture and temperature. In the Intermountain Region most of the plant growth is made in the spring and early summer months. Secondary herbage growth also takes place in many grasses and some forbs during the fall months when the summer foliage is drying or with the return of favorable moisture.

On many domestic and wild grasses and on some forbs part or all of the secondary growth may persist throughout the winter. This is largely determined by snow depth, air temperature, soil temperatures and available moisture and other climatic conditions. Where a deep snow cover is present many grasses begin active growth prior to snowmelt in the spring.

The bunchgrasses; crested wheatgrass, orchardgrass, tall oatgrass, slender wheatgrass, mountain brome and similar grasses produced abundant basal leaves when conditions were especially favorable in the fall. However, when temperatures were low secondary growth was limited and made only by shoots protected by old vegetation, soil or organic material. In the fall of 1958 the snow was shallow and temperatures were low and many of the new shoots produced by native slender wheatgrass and native mountain brome were extending horizontally below the soil surface (fig. 6).

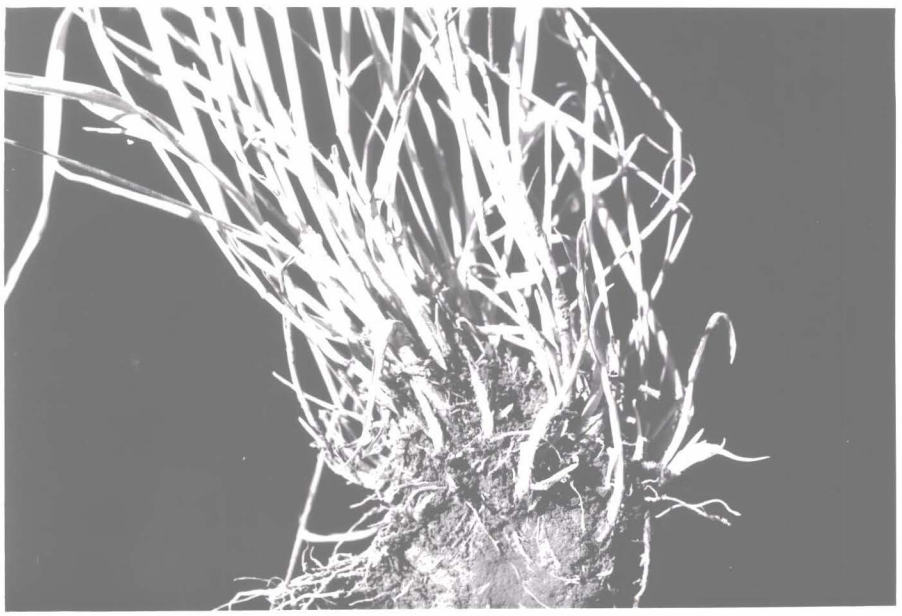


Figure 6 .--New shoots produced by this native slender wheatgrass plant were still below the soil surface on December 8, 1958 and many were extending horizontally (58-273).

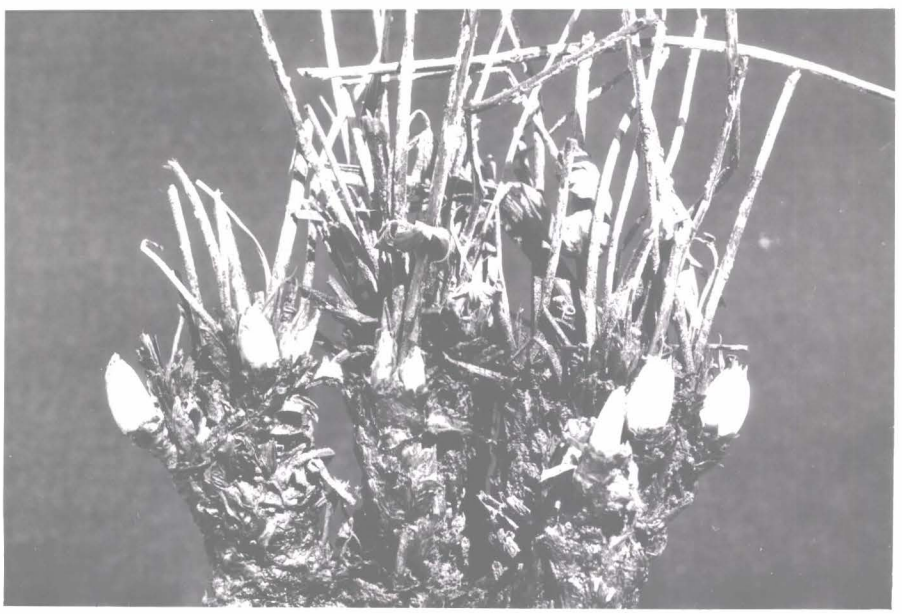


Figure 7 .--New buds form in the crown of Richardson geranium during the fall. These buds persist under the winter snow and produce the early spring shoots (58-264).

The sodgrasses; smooth brome, reed canary and intermediate wheatgrass produced new rhizomes in the fall which emerged and produced new shoots when conditions were favorable. When temperatures were low many of the terminal buds remained below the soil surface until conditions were favorable for plant growth.

Forbs such as Richardson geranium and edible valerian formed new buds in the crown during the fall which persisted under the winter snow (figs. 7 and 8). These buds were usually protected by old growth, soil or organic material but the tips of some plants were exposed and the outer bracts were green and leaflike as shown in the photo of niggerhead (fig. 9).

The rhizomatous forbs; yarrow, Rydberg penstemon, sweetsagebrush and aster produced new rhizomes or shoots in the fall but the terminal buds were usually found just below the soil surface (fig. 10). Still other forbs such as tinpiute gilia, Arabis and Thlaspi produced basal leaves that persisted under the snow throughout the winter months (fig. 11). Plants producing bulbs, tubers or corms such as spring beauties, troutlilies and tuber starwort produced new roots and started to grow in the fall.

Soil freezing occurred during the fall of 1958 before snow fell and while the soil was under a shallow snow cover. When this occurred only limited plant growth took place and secondary herbage growth on grasses and forbs was damaged when very low temperatures occurred before a heavy snow cover was on the ground. However, established plants of many species and fall seedlings of some species remained green in the frozen soil under the snow.

Figure 8 .---Buds form in the crown of edible valerian during the fall and produce the early shoots in the spring. Old growth and outer bracts have been removed to show the buds (58-262).

Figure 9 .---Most of the buds produced by forbs are protected by soil or old growth but where the tips of the buds are exposed the outer bracts are often green and leaflike as on this niggerhead plant (58-266).

Figure 10 .--Rhizomatous forbs such as the sweetsage-brush shown above usually produce many rhizomes in the fall but the terminal buds are usually found just below the soil surface (58-259).

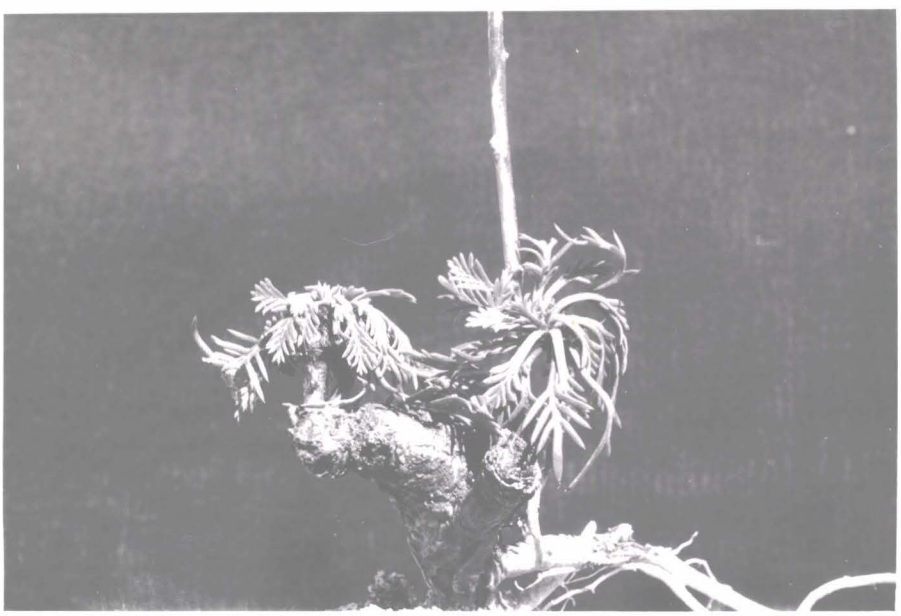
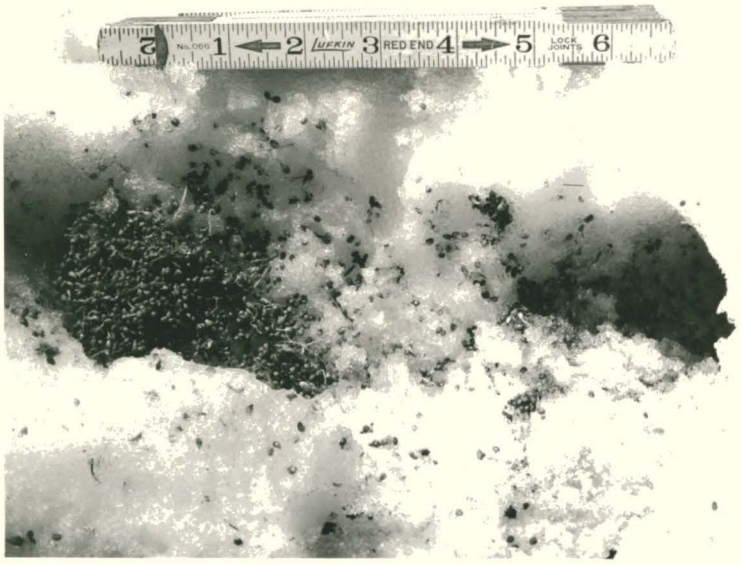


Figure 11 .--Tinpiute gilia produces basal leaves in the fall that persist under the snow throughout the winter (58-256).

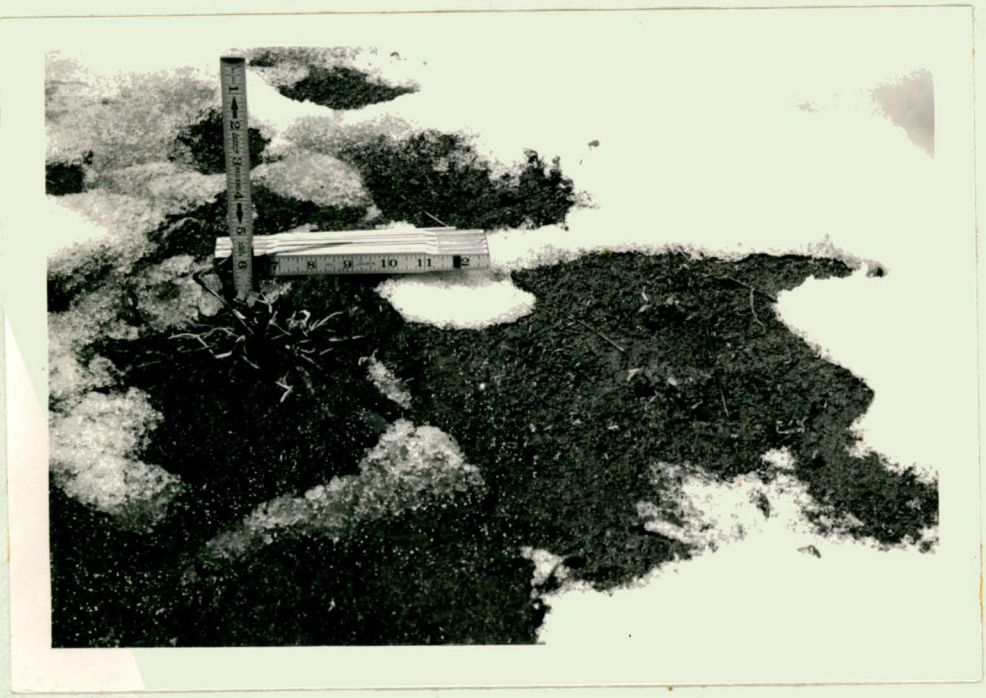
At elevations of over 9,000 feet the soil was not frozen to an appreciable depth during the fall and winters of 1956-1957 and 1957-1958 except where snow cover was shallow. Shallow snow frequently occurred on steep south and west slopes and on wind swept ridges. The soil was frozen to a depth of over 6 inches in the fall and winter of 1958-1959. Observations on soil temperatures at lower elevations have shown that where frozen soil occurred beneath a deep snow cover, thawing of the soil under the snow occurred in late February, March or early April depending on depth of freezing and climatic conditions.

Observations in the winter and spring of 1957 and 1958 have shown that seeds of many species will germinate on or in the soil beneath a deep snow cover and that limited growth will be made by many grasses and forbs prior to spring snowmelt. Seeds have also been observed germinating at or near the surface of the snow during rapid spring snowmelt. In the spring of 1958 a seed cache in a gopher nest in the snow 21 inches above the native soil was observed. As shown in figures 12 and 13 some seeds of Lupinus alpestris and Viola nuttalli in this cache were germinating. Plants such as spring beauties, troutlilies and tuber starwort emerged from the soil under the snow. Native mountain brome and slender wheatgrass shoots up to 2½ inches in length were found under the snow in the spring of 1957 and 1958 (figs. 14 and 15).

Decomposition of organic material under a deep snow cover was marked during the winters of 1956-1957 and 1957-1958. New cotton broadcloth bags buried under snow and soil in the fall of 1956 and 1957



Figures 12 and 13 .--The upper photo shows a portion of a seed cache of Lupinus alpestris and Viola nuttalli found in a gopher nest in the snow 21 inches above the soil surface. The lower photo is a close-up of a portion of this seed.(58-106 and 58-97).



Figures 14 and 15 .--The trench in the upper photo was made in the spring of 1958 just a few days before the snow melted. Note the plants of native mountain brome and slender wheatgrass protruding through the snow in the bottom of the trench. The lower photo shows a plant of mountain brome (58-118 and 58-119).

were largely disintegrated by the time winter snow had melted in the spring of both years. Sacks placed in the snow and in builder's sand above the native soil were also starting to disintegrate but much less than sacks in direct contact with the native soil. Similar decomposition of fine stems and leaves of forbs and grasses has also been noted. Decomposition appears to be primarily due to fungi (fig. 16) and perhaps bacteria. Figure 17 shows a fungi observed growing on the soil surface below a deep snow cover during the spring of 1958.

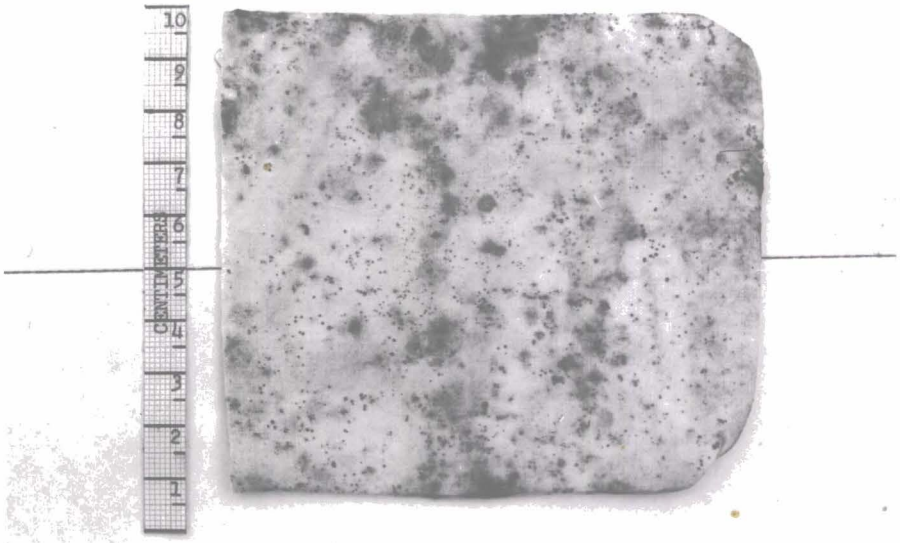


Figure 16 .--Fungi were growing on the cotton bags placed in the snow, sand and soil (58-55).

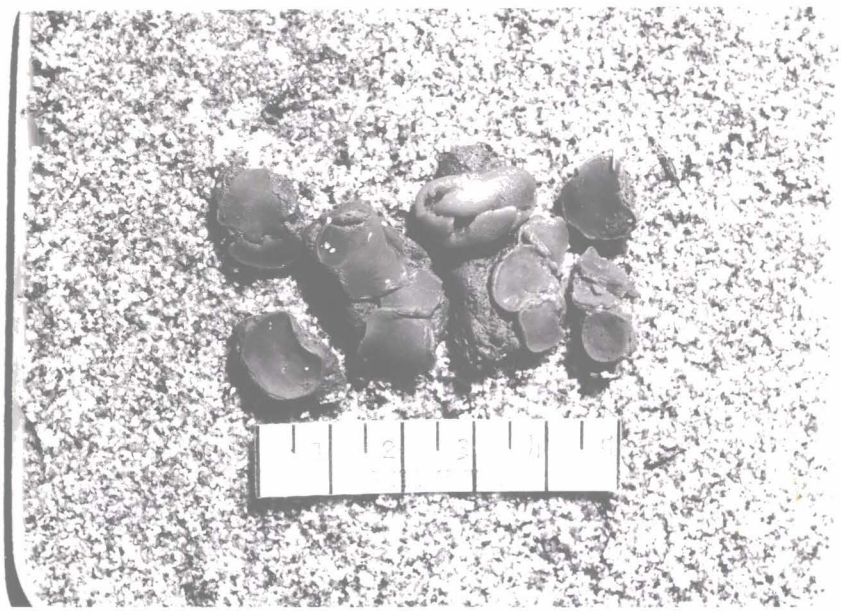


Figure 17 .--Fungi were observed growing on the soil surface under a deep snow cover in the winter of 1957-1958 (58-99).

III-B-1. Stand establishment and free water in the snow and on the soil in the spruce-fir type

Spring plantings at high elevation have usually been successful. Where failures from spring plantings have occurred the reasons have usually been obvious.

Fall plantings at high elevations in central Utah have usually been successful but on some local areas and in other parts of the Intermountain Region fall plantings have failed repeatedly. The reasons for these failures have been obscure since species used, seed quality, depth of planting, competition, available soil moisture and similar factors do not appear to be the cause of these failures. An examination of some of these plantings has shown that good stands are frequently growing on rocky ridges and south or west facing slopes when poor stands are growing on the deep fertile soils in the swales and valleys. High water marks and other signs observed in the spring of 1956 indicated that water reached a depth in excess of 3 and 5 inches, respectively, on two separate test areas. Snow survey notes substantiated these findings and indicated that melted snow water may accumulate under the snow under certain conditions.

To test this theory, free water traps were made by placing a small can, bottom side up, over the top of an open 1/2 quart beverage can, as a loose lid. Small air holes were made on the side of this lid, allowing air to escape when water entered. These cans were fastened together with wire so that bottom of the inverted can was at least 1/2 inch above the top of the beverage can. The larger diameter of the top can gave a

minimum of 1/4 inch of space between the sides of the top can and the beverage can. These traps could only be filled by flowing water. Cans were then buried in the soil so that the lip of the beverage can was 1, 2, or 3 inches above the soil surface. In the fall of 1957 some cans were buried with the lip 1/2 inch above the soil surface.

Traps were buried in the fall of 1956, 1957 and 1958. Results in the spring of 1957 and 1958 follow. Results in the spring of 1959 will not be known until the snow melts in 1959.

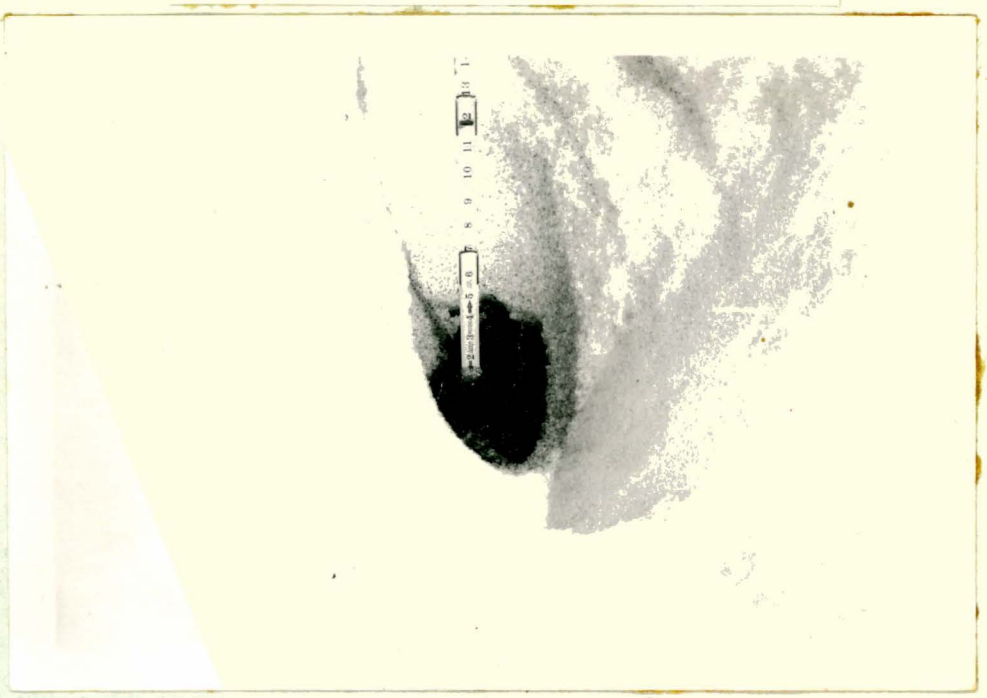
Free water traps installed in the fall of 1956 and other observations demonstrated that flooding under snow occurred under the conditions existing in the spring of 1957. When the cans were checked in the spring of 1957, all cans placed at levels of 1, 2, or 3 inches on shallow, heavy textured soils with slopes less than 5 percent were filled with water. Some cans placed with the opening at 1 inch above a heavy textured soil on slopes of approximately 10 to 15 percent were also filled with water but cans with the opening 3 inches above the soil were not filled. The 2-inch height was not used on this area. All of these areas drain rapidly when the soil is snow free. Six cans, placed with the lip 1-inch above the soil surface on a slope leading to a natural drainage at Manti Ridge, on soil of moderate texture and 2 to 6 feet deep, were all filled with water. The 2- and 3-inch heights were not used at this location. All cans placed on rocky coarse textured soils with the lip 1, 2, or 3 inches above the soil surface were empty in the spring of 1957 and 1958. However, this rocky soil was completely saturated for several hours each day during rapid snowmelt in the spring of 1958 (figs. 18 and 19).

All of the areas tested were on south or southwest slopes with a slope of 5 to 15 percent. Observations made in the winters of 1956-1957 and 1957-1958 indicate that most south and southwest slopes do not have a deep snow cover during the winter months (figs. 20 and 21).

Free water traps put out in the fall of 1957 and inspected in the spring of 1958 indicated that in general depth of free water had been less than it had been in the spring of 1957. This may have been due to less moisture in the snow pack and the snow melted 20 days earlier in the spring of 1958. In general only the cans placed at 1/2 and 1 inch above the soil surface were filled with water. Cans on slopes of more than 5 percent were not filled with water. On June 4 free water from 1/2 to 3 inches deep was observed on Philadelphia Flat when depth of snow was still 20 to 27 inches deep. Figures 22 and 23 show free water in the bottom of a natural pot hole in the snow. Maximum flooding in 1958 occurred on June 6 when a large portion of this flat was covered with water. Depths of water on about 60 acres ranged from 1/2 inch on the higher areas to over 15 inches in some of the drainages.

Figures 18 and 19.---The rocky shallow soil near this snowdrift was completely saturated with water during rapid spring snowmelt in the spring of 1958 (58-68 and 58-69).

Figures 20 and 21.--Snow depths on south and southwest exposures and wind-swept ridges are often quite shallow in comparison to level areas and north exposures (58-101 and 58-71).



Figures 22 and 23 .--Free water from $\frac{1}{2}$ to 3 inches deep was observed on June 4, 1958 when the snow depth on Philadelphia Flat ranged from 20 to 27 inches. Free water can be seen in the bottom of this natural pot hole in the snow (58-116 and 58-117).

Row plantings were usually made adjacent to free water traps so that correlation of seedling stands on these areas could be made with depth of free water. Furrows 20 to 100 feet long and 4 inches deep were made with a hand cultivator. Seeds of smooth brome were planted at a depth of 3/4 inch in the bottom of each furrow with a Planet Jr. Seeding rate with the Planet Jr. was set for 10 pounds per acre when rows were spaced 1 foot apart.

Plantings were made in the fall of 1956 and again in 1957 on the same areas. Seedling stands in the spring of 1957 were included in the 1957 report. Seedling stands in the spring of 1958 and supplemental information are shown below.

1. Philadelphia Flat. Elevation 9,950 feet. Eight furrows near sack study. Poor stands of smooth brome (0.31 plants per foot of row). Cans at 1 level inch were filled with water.
2. Summit Enclosure near uniform study area. Elevation 10,200 feet. Free water traps not filled with water but considerable flooding observed during rapid spring snowmelt. Fair to good stand of smooth brome (0.47 plants per foot of row).
3. Alpine Summit. Elevation 10,200 feet. Snow cover on this west facing area was shallow in comparison to Philadelphia Flat and other level areas (fig. 24). Soil was frozen during most of the winter. Four furrows were made above 1956 seeding. Seeds germinated in the spring. Good seedling stands on June 10, 1958 with 5.2 seeds per foot of row. Frost action and heaving killed some seedlings. Water traps at 1 inch level were not filled.

Figure 24.--Good seedling stands of smooth brome were produced on this wind-swept west facing slope in the spring of 1957 and again in the spring of 1958 (58-48).

4. Rock monument on Skyline Drive. Elevation 10,300 feet. Some seeds just beginning to germinate on June 9, 1958 but many seeds were dead. Three lots of 55 seeds were removed from this area and germinated in the laboratory but only 29 percent of the seeds germinated. Average number of seedlings on the plot area was 0.27 per foot of row. Frost action and heaving killed some plants. Water traps at 1 inch level were filled.

5. Bear Creek. Elevation 9,900 feet. Established on upper portion of a livestock exclosure. Good seedling stands (5.1 plants per linear foot of row). Water traps were not filled on this area.

Additional free water traps and row plantings were placed at selected areas on October 22, 1958 to obtain additional information on free water depths under the snow and during rapid spring snowmelt and the fate of seeds subjected to existing conditions. Traps and rows were placed at the following locations in the fall of 1958.

1. Philadelphia Flat.
   a. near uniform study - traps and 4 rows of smooth brome
   b. near sack study area - traps and 4 rows of smooth brome
   c. every 50 feet from level bottom up a slope for a distance of about 300 feet (maximum slope of about 14%)

2. Near uniform study area at the Summit Enclosure - west of 1957 study with 4 rows of smooth brome.
3. Head of Ephraim Canyon above the alpine cabin - traps and 4 rows of smooth brome.
4. Monument on Skyline Drive south of John August Lake - traps and 2 rows of smooth brome just east of monument.
5. Bear Creek Flat area - west plot - 3 rows of smooth brome.
6. Manti Canyon seeding - traps at 3 separate locations with 2 rows of smooth brome at each location.

III-B-2. Uniform study for seeding depleted sites on western range

Plans to establish a uniform study were first made at the Range Society Meetings held at Great Falls in January 1957. This study was conducted at six locations, as follows: Bozeman, Montana; Ephraim, Utah; La Grande, Oregon; Logan, Utah; Pullman, Washington; and Reno, Nevada. A general plan of study was made from the composite suggestions by Dr. Keller and the field men located at the locations shown above. A. C. Hull acted as coordinator, and assembled this material into study plan form.

Major treatments included 9 seedbed treatments to be applied on the contour and 5 fertilizer treatments applied up and down the slope at right angles to seedbed treatments. The uniform treatments are shown below.

Seedbed treatment

1. Plow fall 1957 - fallow - seed fall 1958
2. Nurse crop fall of 1957 - seed fall 1958
3. Plow fall 1957 - seed spring 1958
4. Spray spring 1958 - seed fall 1958
5. Plow, seed, and sawdust mulch plus nitrogen, fall 1957
6. Plow, contour furrows, seed fall 1957
7. Plow fall 1957 - transplants fall 1957 or spring 1958
8. Plow and seed fall 1957
9. Check plot - no soil preparation or planting

Plantings were made according to plan on Philadelphia Flat, elevation approximately 10,000 feet, and at the Summit Enclosure, elevation 10,200 feet, in Ephraim Canyon the fall of 1957 and again in the fall of 1958. The two areas are about 2 miles apart. The nine seedbed treatments were applied at random on the contour. Five fertilizer treatments were applied up and down the slope at right angles to seedbed treatment. Plantings were made on Forest Service land within enclosures constructed by the Forest Service.

The 1957 plantings were made on October 10 and October 18. Snow covered the Philadelphia Flat area after October 12 and the Summit Enclosure was covered by new snow on October 18, 1957. Major species planted were native slender wheatgrass, tall oatgrass, native mountain brome, smooth brome and red fescue. Secondary species included meadow foxtail, orchardgrass, chewing fescue, intermediate wheatgrass and stiffhair wheatgrass.

The Summit area was partly free of snow on June 2, 1958. All furrows were filled with water and water was running over all plots. This area was free of snow on June 4 (fig. 25). Transplants were made on June 6 and spring planting was completed on June 13. The Philadelphia Flat area was free of snow on the afternoon of June 7. This area was under ½ to 1½ inches of water on the afternoon of June 6. Seed was planted on spring plant plots on June 10 and transplants were made on June 12.

Number of plants on all plots were counted at both study areas on July 9, August 5 and September 2 or 3, 1958. On Philadelphia Flat the valley soil plot was superior to other treatments (figs. 26 and 27). Complete fertilizer treatments were usually superior to the check plot and other fertilizer treatments on fall seeded plots (table 5). Difference in plant numbers between the fall drill, contour-furrow and sawdust mulch plot were small but these treatments were superior to fall drill-spray in spring treatments and spring plant treatments (tables 6 and 7). Native species were usually superior to domestic grasses.

On the Summit area the sawdust mulch plot produced a better stand than other treatments (table 8). Plant numbers were low on other treatments except for the plots planted in the spring. Fertilizer did not appear to have an effect on stands produced (table 9). Native

Figure 25 .--The Summit area at an elevation of 10,200 feet was free of snow on June 4, 1957. (58-105)

Figure 26 .--The valley soil plot in the foreground produced the best stands on Philadelphia Flat in the spring of 1958 (58-226).

Figure 27 .--Native slender and native mountain brome produced fair to good stands on the contour furrow plot in the spring of 1958 (58-229).

Table 5 .--Number of plants by fertilizer treatments per foot of row on 7 seeding treatments on Philadelphia Flat in 1958.

Fertilizer	Planted: Fall-1957: Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Spring-1958: Drill
			July 9, 1958				
Check-None	1.42	2.88	14.05	1.94	2.02	4.00	.00
Nitrogen	1.70	2.64	-	1.88	2.14	-	.00
Phosphorus	.88	3.40	-	1.84	2.74	-	.00
Nitrogen + phosphorus	.92	3.76	-	2.48	1.92	-	.00
Complete	1.52	3.84	-	2.82	3.64	-	.00
Total	6.44	16.52		10.96	12.46		-
Average	1.29	3.30	14.05	2.19	2.49	4.00	.00
			August 5, 1958				
Check-None	1.20	2.06	10.20	1.48	1.32	3.58	.08
Nitrogen	.74	1.43	-	1.98	1.74	-	.04
Phosphorus	.46	2.04	-	1.90	1.80	-	.06
Nitrogen + phosphorus	.72	2.26	-	2.28	1.58	-	.00
Complete	1.06	3.80	-	2.30	2.84	-	.00
Total	4.18	11.59		9.94	9.28		.18
Average	.84	2.32	10.20	1.99	1.86	3.58	.04
			September 3, 1958				
Check-None	1.08	2.38	12.80	1.96	2.02	4.34	.98
Nitrogen	.80	1.78	-	2.52	2.50	-	.80
Phosphorus	.64	2.34	-	2.12	2.38	-	1.26
Nitrogen + phosphorus	1.20	2.60	-	2.66	2.22	-	.80
Complete	.94	4.04	-	2.72	3.84	-	.50
Total	4.66	13.14		11.98	12.96		4.34
Average	.93	2.63	12.80	2.40	2.59	4.34	.87

Table 6 .--Number of plants per foot of row on 7 treatments and 3 dates in 1958 on Philadelphia Flat.

Species	Planted: Fall-1957: Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Planted: Spring-1958: Drill
			July 9, 1958				
Slender wheatgrass	4.00	8.80	13.50	4.32	5.98	11.10	.00
Tall oatgrass	.12	.36	8.00	.14	.36	.10	.00
Mountain brome	1.98	6.66	17.20	6.76	5.08	8.30	.00
Smooth brome	.20	.16	12.00	.08	.32	.10	.00
Red fescue	.18	.54	19.50	.22	.72	.40	.00
Total	6.48	16.52	70.20	11.52	12.46	20.00	-
Average	1.30	3.30	14.04	2.30	2.49	4.00	.00
			August 5, 1958				
Slender wheatgrass	2.06	6.42	14.50	3.56	4.38	10.60	.00
Tall oatgrass	0.00	.04	5.00	0.00	.02	0.00	.00
Mountain brome	2.12	5.17	18.20	6.36	4.68	7.00	.00
Smooth brome	0.00	.02	9.50	.02	.12	.20	.18
Red fescue	0.00	0.00	3.50	0.00	.08	..10	.02
Total	4.18	11.65	50.70	9.94	9.28	17.90	.20
Average	.84	2.33	10.14	1.99	1.86	3.58	.04
			September 3, 1958				
Slender wheatgrass	1.72	7.04	22.50	4.40	6.34	13.00	.06
Tall oatgrass	.04	0.00	5.50	0.00	.02	0.00	.82
Mountain brome	1.76	6.08	23.50	7.40	6.50	8.50	.50
Smooth brome	.34	.02	9.50	.06	.10	.20	1.84
Red fescue	0.00	0.00	3.00	.02	0.00	0.00	1.12
Total	3.86	13.14	64.00	11.88	12.96	21.70	4.34
Average	.77	2.63	12.80	2.38	2.59	4.34	.87

Table 7 .--Number of plants by species and by fertility treatment per foot of row on the Buffer plot at Philadelphia Flat and Summit Enclosure in 1958.

	Philadelphia Flat			Summit Enclosure		
Species	7/9	8/5	9/3	7/9	8/5	9/3
Meadow foxtail	.12	.00	.04	.02	.02	.40
Orchardgrass	.34	.00	.00	.20	.16	1.72
Chewing fescue	1.18	.00	.00	.00	.00	1.10
Intermediate wheatgrass	.10	.04	.00	.36	.26	4.14
Stiffhair wheatgrass	.22	.34	.14	.80	.70	.78
Total	1.96	.38	.18	1.38	1.14	8.14
Average	.39	.08	.04	.28	.23	1.63
Fertilizers						
Check-None	.18	.14	.98	.30	.28	1.78
Nitrogen	.62	.04	.80	.28	.26	2.08
Phosphorus	.26	.08	1.26	.10	.04	1.08
Nitrogen + phosphorus	.48	.04	.80	.28	.28	1.46
Complete	.42	.08	.94	.42	.28	1.74
Total	1.96	.38	4.78	1.38	1.14	8.14
Average	.39	.08	.96	.28	.23	1.63

Table 8 . Number of plants per foot of row on 7 treatments and 3 dates in 1958 on Summit Enclosure.

Species	Planted						
	Fall-1957						Spring-1958
	Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Drill
			July 9, 1958				
Slender wheatgrass	0.00	.22	1.25	1.00	10.46	9.30	.04
Tall oatgrass	0.00	.02	.50	.04	.92	.50	.98
Mountain brome	0.00	.02	0.00	.41	3.84	3.30	.00
Smooth brome	0.00	.02	2.00	.28	2.90	4.20	2.08
Red fescue	0.00	.08	0.00	.54	3.90	4.30	.24
Total	-	.36	3.75	2.27	22.02	21.60	3.34
Average	0.00	.07	.75	.45	4.40	4.32	.67
			August 5, 1958				
Slender wheatgrass	.04	.18	.75	.92	8.06	6.20	.00
Tall oatgrass	0.00	.02	0.00	.04	1.56	1.80	.70
Mountain brome	0.00	0.00	0.00	.20	3.48	3.30	.00
Smooth brome	0.00	.08	1.50	.26	2.72	5.90	1.64
Red fescue	0.00	0.00	.50	.08	1.90	3.60	.09
Total	.04	.28	2.75	1.50	17.72	20.80	2.43
Average	.01	.06	.55	.30	3.54	4.16	.49
			September 2, 1958				
Slender wheatgrass	0.00	.28	.02	.82	7.90	7.20	.08
Tall oatgrass	0.00	.02	0.00	.04	1.30	1.80	1.76
Mountain brome	0.00	0.00	0.00	.20	3.00	3.30	.94
Smooth brome	0.00	.04	0.00	.22	2.04	3.90	7.58
Red fescue	0.00	0.00	0.00	.08	1.70	3.60	1.60
Total	-	.34	.02	1.36	15.94	19.80	11.96
Average	0.00	.07	T[1]	.27	3.19	3.96	2.39

1/ Numbers less than .01 = Trace

Table 9 .--Number of plants by fertilizer treatments per foot of row on 7 seeding treatments on Summit Enclosure in 1958.

Fertilizer	Planted: Fall-1957: Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Spring-1958: Drill
			July 9, 1958				
Check-None	0.00	.06	.75	.28	3.94	4.32	.66
Nitrogen	0.00	.08	-	.20	4.26	-	.52
Phosphorus	0.00	.04	-	.46	5.72	-	.28
Nitrogen + phosphorus	0.00	.10	-	.60	4.62	-	1.12
Complete	0.00	.08	-	.74	3.48	-	.76
Total		.36		2.28	22.02		3.34
Average	0.00	.07	.75	.46	4.40	4.32	.67
			August 5, 1958				
Check-None	0.00	.04	.55	.20	2.46	4.16	.48
Nitrogen	0.00	.06	-	.20	2.96	-	.32
Phosphorus	0.00	0.00	-	.32	4.36	-	.26
Nitrogen + phosphorus	.04	.14	-	.40	4.20	-	.90
Complete	0.00	.04	-	.38	3.74	-	.44
Total	.04	.28		1.50	17.72		2.40
Average	.01	.06	.55	.30	3.54	4.16	.48
			September 2, 1958				
Check-None	0.00	.06	.01	.65	2.30	3.96	2.30
Nitrogen	0.00	.04	-	.18	2.66	-	2.14
Phosphorus	0.00	.02	-	.26	4.14	-	2.50
Nitrogen + phosphorus	0.00	.18	-	.38	3.58	-	3.14
Complete	0.00	.04	-	.40	3.24	-	1.88
Total		.34		1.87	15.92		11.96
Average	0.00	.07	.01	.37	3.18	3.96	2.39

slender wheatgrass and native mountain brome produced the best stands on the plots planted in the fall but intermediate wheatgrass and smooth brome produced the best stands on the plots planted in the spring (table 7).

Difference between the Philadelphia Flat area and the Summit Enclosure appear to be largely due to exposure. The Summit area is on an 8 percent west facing slope while Philadelphia Flat is on a near level terrace with a slight north slope. Snow melts from the Summit area a few days before it leaves Philadelphia Flat. The Summit area is also often free of snow later in the fall than the relatively level Philadelphia Flat. This favors frost action and heaving and may also result in earlier germination of seeds on the Summit area.

III-B-3. Pocket gophers on rangelands

Pocket gopher workings have been numerous on most harsh sites at high elevations in Utah where the vegetative cover has been depleted. Gopher activities have been followed and studied because pocket gophers have damaged seedling stands, damaged or destroyed established plants, especially plants with single taproot, and have been a constant bother where seed germination studies under snow have been conducted.

Pocket gophers were trapped in the fall of 1957 and 1958 on and near all study areas at high elevations. Records were not kept on animal numbers in the fall of 1957 but record of total animals caught were kept on an area of about four acres on Philadelphia Flat. Trapping on this area started in September and continued until the end of November. A total of 63 animals or 15.8 animals per acre were trapped. Many of these animals were small and were probably young adults but age or sex of animals was not recorded.

The activity of gophers during the fall and winter months, especially after snow covers the ground appears to be largely determined by soil temperature and moisture. In the fall of 1956, 1957 and 1958 many mounds were made after the soil was moistened in the fall. Pocket gopher activity just after the first snow in the fall was marked in 1956 and 1957 when the soil was frost free but only limited gopher activity was noted in the frozen soil in the fall of 1958. Moderate gopher activity was observed in November, December and January of 1957-1958 but only limited activity was observed in 1958-1959 when the soil was frozen.

Gopher activity in the snow above the soil surface increased markedly after February-March of 1957, 1958 and 1959 and continued until snowmelt in the spring. The increased activity after the February-March period appears to be related to thawing of the soil when it has been frozen, an increase in temperatures of the surface soil and snow near the soil surface, a depletion of stored food reserves, additional food supply provided by an elongation of grasses and forbs and a need for storage space for soil and waste material.

Most of the burrows and soil casts observed in the snow were within 3 inches of the soil surface but one cast 27 inches above the soil surface was found in the spring of 1958. On June 5, 1957 many soil casts and nests and a few food caches were found from 18 to 22 inches above the soil surface at Franklin Basin in Logan Canyon (figs. 28 and 29). A few scattered nests and food caches from 15 to 26 inches above the ground have been found at high elevations in Ephraim Canyon. Nests found in the snow have usually been lined with dried grass or shredded bark (fig. 30).

Gopher damage was rather severe on the study areas on Philadelphia Flat in the spring of 1957 and 1958 (fig. 31). Where casts were placed in the snow on or near the soil surface the casts often followed depressions in the soil such as furrows. On furrowed plots where gophers were active, from 11 to 37 percent of the drill rows in the bottoms of the furrows were covered with soil casts. These casts were usually $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter, thus seeds and seedlings were often covered with 2 to 3 inches of soil when casts were placed in the bottom of the

furrows directly over the seed. Some damage to established plants was observed when casts covered the crowns but mortality of these plants did not appear to be high. However, established plants were often killed when the root system was destroyed by gophers burrowing beneath the plants. Some damage was also observed where gophers dug up the roots of dandelions and other plants as shown in figures 32 and 33.

Pocket gopher activity may have a pronounced influence on the water level in snow especially on slopes. Soil casts up to 2½ inches in diameter placed along the slopes by the gophers may act as small dams to back up the water. On the other hand, gopher holes often provide rapid drainage for large volumes of water. Drainage through gopher holes may be in channels under the soil surface (fig. 34) or under the snow on the soil surface.

Pocket gophers apparently eat a wide variety of plants. Food caches observed frequently contained roots, tubers, corms and bulbs which are usually harvested while burrowing in the soil. Heavy utilization of grasses and forbs above ground have been observed in the vicinity of burrow openings. Limited utilization of green grasses and forbs under the snow has also been observed. Seeds of Lupinus alpestris and Viola nuttalli made up a food cache found in a gopher nest in the snow in the spring of 1958 (fig. 12). During rapid spring snowmelt in the spring of 1958 a gopher ate seeds of slender wheatgrass, tall oatgrass, mountain brome and slender wheatgrass that had been placed in small cloth bags and suspended in the snow.

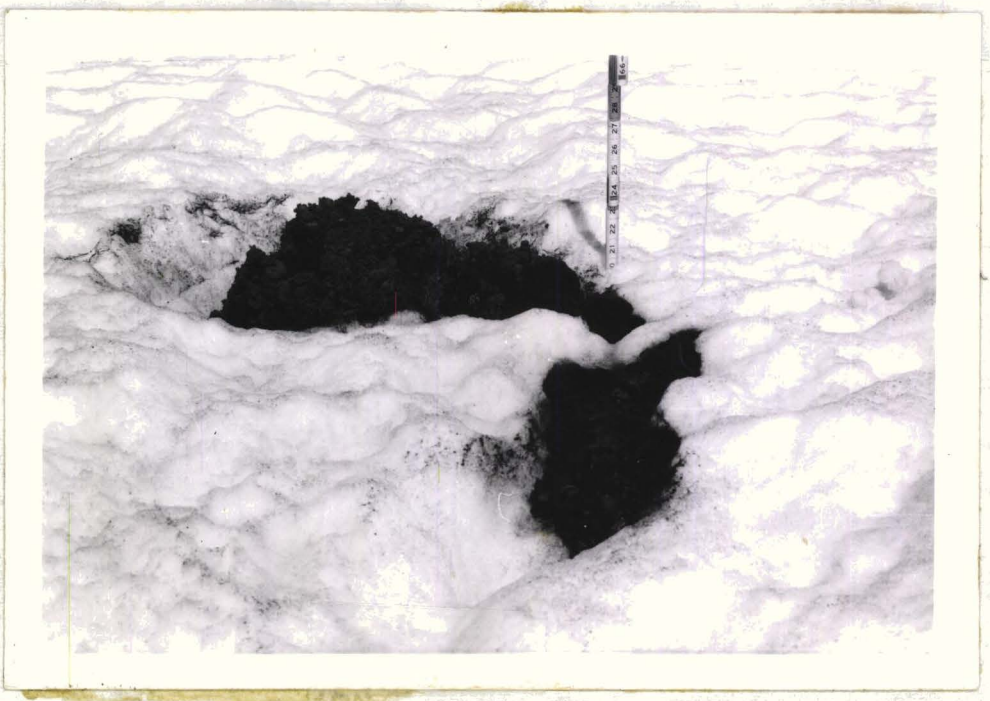


Figure 28 .--This pocket gopher nest in the snow is over 20 inches above the soil surface. The tunnel leading to the nest and part of the nest was filled with soil (57-29).

Figure 29 .--The food cache in the foreground consists of bulbs of troutlily, corms of spring beauties and tubers of starwort. The food cache, soil casts and burrows in snow are about 18 inches above the soil surface (57-32).

Figure 30 .--Gopher nests were usually lined with dried grass. The tunnel leading to this nest had been filled with soil (57-34).

Figure 31 .--Soil casts placed on the soil surface and in the snow often cover seeds, seedlings and established plants (58-148).

Figures 32 and 33.--Pocket gophers dug out dandelion roots in the spring of 1958 prior to snowmelt. Soil compaction and trenches in the snow indicate soil was very wet when roots were dug (58-161 and 58-162).

Figure 3 4 .--Water was still flowing from pocket gopher burrow in the spring of 1958 although all snow had melted except on the ridge in the background (58-122).